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THE EVERGLADES NATIONAL PARK CREEL SURVEY

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Introduction

Smalltooth sawfish, *Pristis pectinata*, historically were found from Texas to New York. However, the population today is approximately 5% of its original size and restricted primarily to the waters of southern Florida, especially Everglades National Park and adjacent areas (Seitz and Poulakis, 2002; Poulakis and Seitz, 2004; Simpfendorfer and Wiley, 2005). The decline of smalltooth sawfish has been attributed to catch and bycatch in commercial and recreational fishing, habitat loss, and a vulnerable life history (Simpfendorfer, 2002, 2005). In response to the decline in the population, the National Marine Fisheries Service (NMFS) listed this species as Endangered under the US Endangered Species Act in April 2003 (68 FR 15674).

Everglades National Park (ENP) was established in 1947, and a fishery-monitoring program based on sport fisher dockside interviews by the National Park Service (NPS) began in 1972 (Davis and Thue, 1979; Tilmant et al., 1986; Schmidt et al., 2002). In a previous study, Carlson et al. (2007) provided a relative index of abundance of smalltooth sawfish based on the dockside monitoring of the recreational fishery in ENP from 1989-2004. Results from that study indicated the population was stable with some evidence of an increasing trend in abundance ($\sim 5\% \text{ yr}^{-1}$). The recovery strategy for smalltooth sawfish requires that the species is present in numbers sufficient throughout the core of its historic range and in numbers sufficient to eliminate the risk of extinction in the foreseeable future (NMFS, 2009). As few long-term abundance indices are available for smalltooth sawfish, the objectives of this study were to provide an update to the analysis in Carlson et al. (2007).

Methods

Data collection and analysis followed methods outlined in Carlson et al. (2007). Briefly, a subset of the ENP dataset 1989-2004 was developed using the species composition of the catch and the species most associated with the catch of a smalltooth sawfish. Carlson et al. (2007) identified goliath grouper, *Epinephelus itajara*, nurse shark, *Ginglymostoma cirratum*; blacktip shark, *Carcharhinus limbatus*; unidentified carcharhinid shark, pinfish, *Lagodon rhomboides*; tarpon, *Megalops atlanticus*, red drum, *Sciaenops ocellatus*, snook, *Centropomus* spp., crevalle jack, *Caranx hippos*, and gafftop catfish, *Bagre marinus* as species with the highest association statistic (Table 1).

Following Carlson et al. (2007), several categorical variables were constructed from the ENP data set prior to analysis. The factor “fisher” refers to the skill level of the fishing party. Based on Cass-Calay and Schmidt (2003), two levels were considered from the data: “skilled” = fishers identified as “skilled” by ENP personnel and “other” = fishers identified as “family,” “novice,” or “sustenance”. The factor “season” was developed from “month” to create two periods reflective of rainfall in the ENP: “wet”= June-November and “dry”=December-May. The factor “target” was defined using the reported species preference. As smalltooth sawfish were never reported as a preferred species, species targeted that used a technique thought to influence the capture a smalltooth sawfish included: tarpon, red drum, grey snapper, *Lutjanus griseus*, snook, spotted sea trout, *Cynoscion nebulosus*, and shark. All other species were categorized as “other.” The factor “area” describes where the fisher reported fishing and defined as “Inner Florida Bay,” “Outer Florida Bay,” “Whitewater Bay,” “Ten Thousand Islands,” and “other” (no area or multiple areas were identified) (Figure 1).

Relative indices of abundance for smalltooth sawfish were estimated by generalized

linear modeling (GLM) using the Delta method (Lo et al., 1992) that involves fitting two ‘sub-models’ to the data (Lo et al., 1992). The first sub-model involves modeling the probability of a non-zero catch, assuming a binomial error distribution, and a second sub-model where the catch is non-zero and the distribution is assumed to be lognormal. Following Ortiz and Arocha (2004), factors most likely to influence abundance were evaluated in a forward stepwise fashion. Initially, a null model was run with no factors entered into the model. Models were then fit in a stepwise forward manner adding one independent variable. Each factor was ranked from greatest to least reduction in deviance per degree of freedom when compared to the null model. The factor with the greatest reduction in deviance was then incorporated into the model, providing the effect was significant at $p < 0.05$ based on a Chi-Square test, and the deviance per degree of freedom was reduced by at least 1% from the less complex model. The process was continued until no factors met the criterion for incorporation into the final model. Regardless of its level of significance, “year” was kept in all models. This allows the estimation of the annual indices, which is the main objective of the standardization process, but also accounts for the variability associated with year-interactions (Cooke, 1997 Not in references). After selecting the set of factors for each error distribution, all factors that included “year” were treated as random interactions (Ortiz and Arocha, 2004). The standardized CPUE values for the Delta model was calculated as the product of the expected probability of a non-zero catch and the expected conditional catch rate for sets that had a non-zero catch. The expected probability and expected conditional catch rate were the least square means of the factor year from each of the two analyses that constitute an analysis using the Delta model approach (Lo et al., 1992; Stefansson, 1996). All models were fit using a SAS macro, GLIMMIX (glmm800MaOB.sas: Russ Wolfinger, SAS Institute Inc.), and the MIXED procedure in SAS statistical computer software

(PROC GLIMMIX).

Final models were selected based on Akaike Information Criteria (AIC). Models of positive catches were checked for appropriate fit and diagnostics by examining the residuals plotted against the fitted values to check for systematic departures from the assumptions underlying the error distribution; the absolute values of the residuals plotted against the fitted values as a check of the assumed variance function; and the dependent variable was plotted against the linear predictor function as a check of the assumed link function (McCullagh and Nelder, 1989).

Results and Discussion

After refinement using the association statistic, the final data set used to estimate the standardized index of abundance contained 65,829 trips. At least one smalltooth sawfish was reported caught in 0.25% of those trips.

For the binomial model, “year,” and “season” were significant as main effects. These two factors explained 2.2% of the deviance from the null model (Table 2). When modeling the positive trips, factors “year” and “fisher” were found to be significant explaining less than 2% of the final deviance from the null model (Table 3). The final mixed models for standardizing catch rates are in Table 4. No significant interactions were found.

Diagnostic plots assessing the fit of the lognormal model were deemed acceptable (Figure 2). The frequency distribution of the natural logarithm of CPUE and residuals approximated a normal distribution. When plotted by year, the residuals were distributed evenly around zero. The quantile-quantile plot of the data tended to fall along the reference line indicating the data are from a normal distribution. In summary, all diagnostic plots met assumptions and supported

an acceptable fit to the selected model.

The standardized relative catch rate series indicated the population was stable to slightly increasing although variation is high (Figure 3). The relative (catch per unit effort /mean of the index) standardized catch per unit effort was highest in 2002 and lowest in 1991. A linear regression on the relative catch per unit effort resulted in a positive slope (0.045, $r^2=0.20$, $p=0.032$). However, 95% confidence limits were high due to small sample size indicating little reliability in the trend.

Smalltooth sawfish are among those elasmobranchs with the lowest productivities (Musick et al., 2000; Simpfendorfer, 2000) and recovery for this species will likely take decades. Carlson et al. (2007) found smalltooth sawfish may be increasing within the ENP at a rate of about 5% year⁻¹ from 1989-2004 and results from this updated analysis indicate the trend is still increasing although variability was high. Evidence from other data sources also indicates the current population of smalltooth sawfish is at least stable throughout its core with the potential for the core area of abundance to be expanding. Data based on public encounters (Wiley and Simpfendorfer, 2010) shows the 95% core area to have expanded to areas along the southwest coast of Florida (G. Burgess, University of Florida, personal communication). These results suggest current management recommendations outlined in the recovery plan (NMFS, 2006) have been successful in stopping the decline of smalltooth sawfish and may be improving the status of the species.

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Table 1. Species found to be related through the association statistic with the catch of smalltooth sawfish in Everglades National Park (from Carlson et al., 2007).

Common Name	Scientific Name	Association statistic
Goliath grouper	<i>Epinephelus itajara</i>	3.45
Nurse shark	<i>Ginglymostoma cirratum</i>	2.78
Blacktip shark	<i>Carcharhinus limbatus</i>	2.63
Requiem shark	Carcharhinidae	2.62
Pinfish	<i>Lagodon rhomboides</i>	2.16
Tarpon	<i>Megalops atlantica</i>	2.03
Snook	<i>Centropomus</i> spp.	2.03
Red drum	<i>Sciaenops ocellata</i>	1.74
Crevalle jack	<i>Caranx hippos</i>	1.20
Gafftopsail catfish	<i>Bagre marinus</i>	1.05

Table 2. Analysis of deviance of explanatory variables for the binomial generalized linear model of the proportion of positive smalltooth sawfish captures. Factors were added to the model if the factor was significant based upon a Chi-Square test ($p < 0.05$) and the reduction in deviance per degree of freedom (Deviance/DF) from the null model was at least 1%. AIC= Akaike Information Criterion.

FACTOR	DEVIANCE/DF	%DIFF	DELTA%	CHISQUARE	PR>CHI	AIC
NULL	0.3389					
YEAR	0.2992	11.714	11.714	55.94	<.0001	638.4
YEAR+						
SEASON	0.2915	13.986	2.272	9.72	0.0018	630.7
TARGET	0.2926	13.662		9.52	0.0901	638.9
AREA	0.2958	12.718		5.65	0.3419	642.8
FISHER	0.2983	11.980		1.39	0.2388	639.1

Table 3. Analysis of deviance of explanatory variables for the delta generalized linear model of smalltooth sawfish positive captures assuming a lognormal distribution. Factors were added to the model if the factor was significant based upon a Chi-Square test ($p < 0.05$) and the reduction in deviance per degree of freedom (Deviance/DF) from the null model was at least 1%. AIC= Akaike Information Criterion.

FACTOR	DEVIANCE/DF	%DIFF	DELTA%	CHISQUARE	PR>CHI	AIC
NULL	0.4566					
YEAR	0.4572	-0.131	-0.131	21.28	0.3807	348.3
YEAR+						
FISHER	0.4491	1.643	1.774	4.03	0.0447	346.2
SEASON	0.4584	-0.394		0.75	0.3856	349.5
AREA	0.4638	-1.577		3.59	0.6096	354.7
TARGET	0.4672	-2.322		2.44	0.7851	355.8

Table 4. Factors retained in the final models of proportion of positive sets (binomial) and positive catch (log normal) of smalltooth sawfish for the generalized linear models with associated Akaike Information Criterion (AIC). An asterisk indicated final model chosen.

Model	Factors	AIC
Binomial	YEAR+SEASON	53.7
	YEAR+SEASON YEAR*SEASON	63.3
Lognormal	YEAR+FISHER	321.5
	YEAR+FISHER YEAR*FISHER	321.5

Figure 1. Map of Everglades National Park illustrating the defined fishing areas and the boat launch ramps where fishers were interviewed. Chokoloskee boat ramp is illustrated with a filled square and Flamingo boat ramp is illustrated with a filled circle.

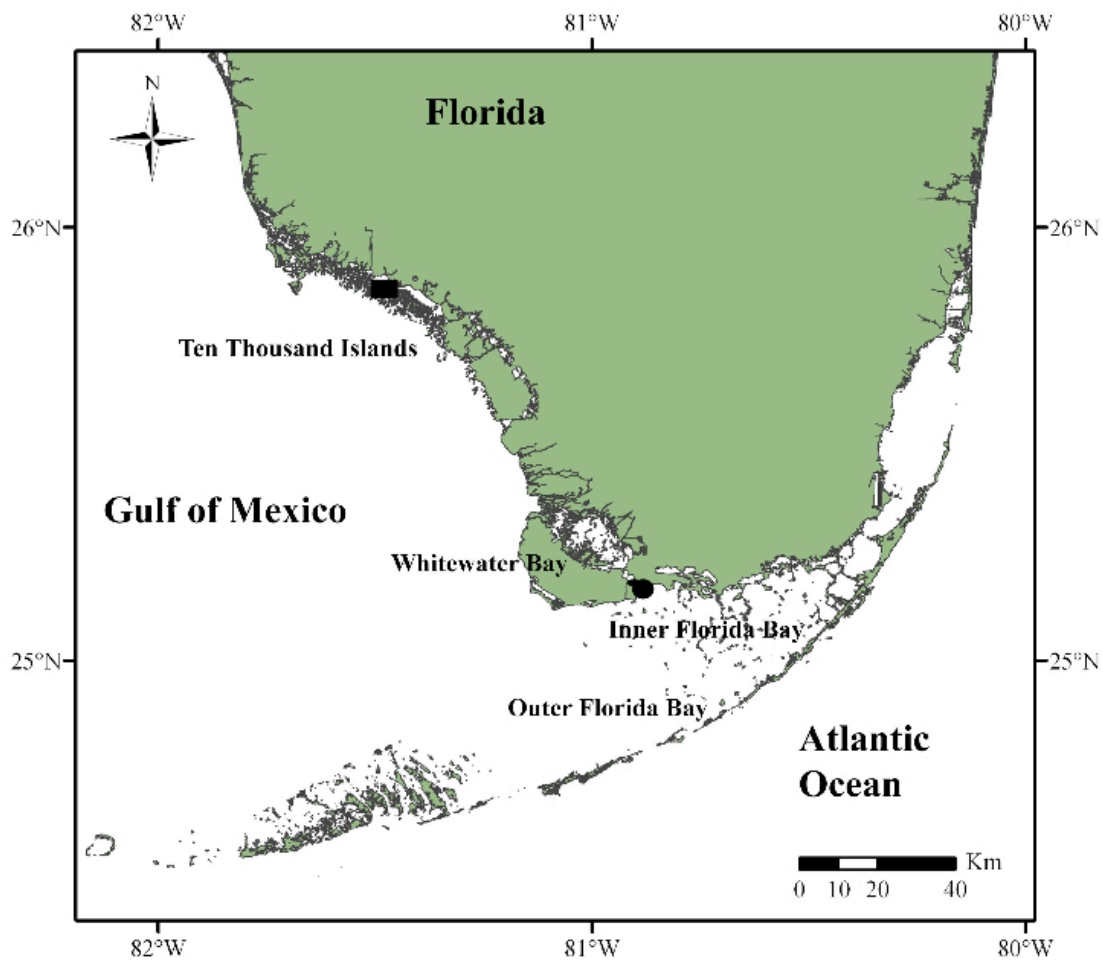


Figure 2. Distribution of the natural logarithm of the catch per unit effort data and diagnostic plots of the frequency distribution of residuals, quantile-quantile plots, and distribution of residuals by year from the lognormal model.

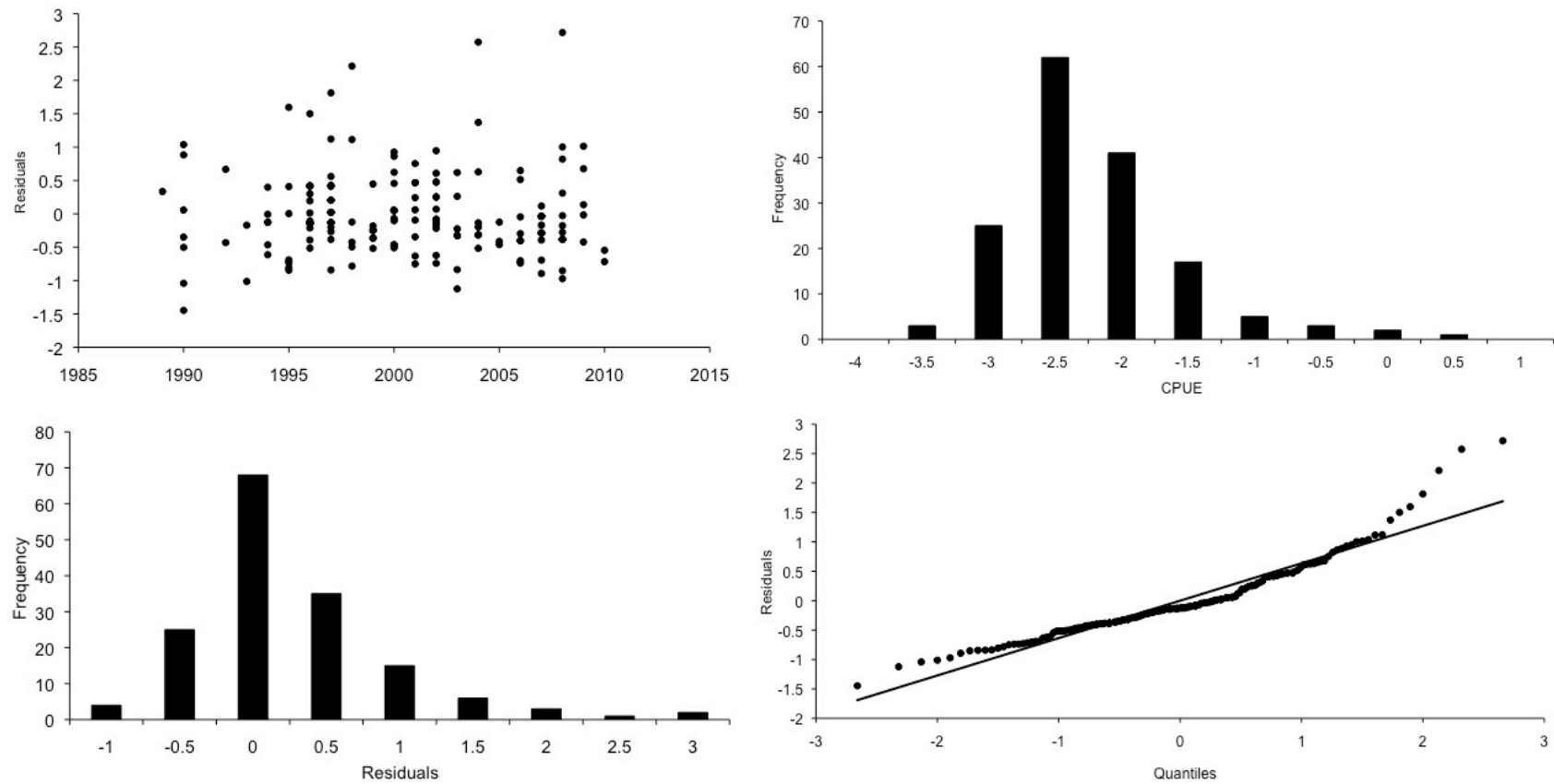


Figure 3. Standardized relative index of abundance (index/maximum of the index) for smalltooth sawfish from the Everglades National Park Creel Survey interview data based on the final delta model. Dashed lines represent the upper and lower 95% confidence limits.

